

Landsat's Long-Term Acquisition Plan

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Presented By:
Eugene A. Fosnight
Landsat Data Acquisition Manager
fosnight@usgs.gov

Agenda

- The Landsat Long-Term Acquisition Plan
- LTAP modeling
- Special Requests for Acquisition

Science Goals

- The Landsat mission is driven by the requirement to create a long-term environmental record guided by the Long-Term Acquisition Plan
- Individual user requests and science campaigns are accepted, but only so far as they do not perturb the Long-Term Acquisition Plan.
 - Individual user requests are most likely to be accepted if they have associated field campaigns or are for emergency response. Night acquisitions are only acquired by special request.
 - Science campaigns tend to target areas associated with large mapping projects for which the temporal period is well defined, occasionally repeating, and tend to have a low priority boost leading to a moderated increase in the probability of acquisition.
- To meet these goals the Landsat Long-Term Acquisition Plan continues to evolve through lessons learned in response to new inputs, aging satellites, and new satellite capabilities

LTAP Components

- **What to acquire**

- ◆ Global Archive Refresh
- ◆ Calibration
- ◆ Special requests

- **When to acquire it**

- ◆ Characterization of phenology (seasonality)
- ◆ Cloud avoidance
- ◆ Solar zenith angle constraints

- **How to balance all objectives**

- ◆ Priority schema
- ◆ Priority-based scheduling rules
- ◆ Feedback from the archive (cloud cover and quality)

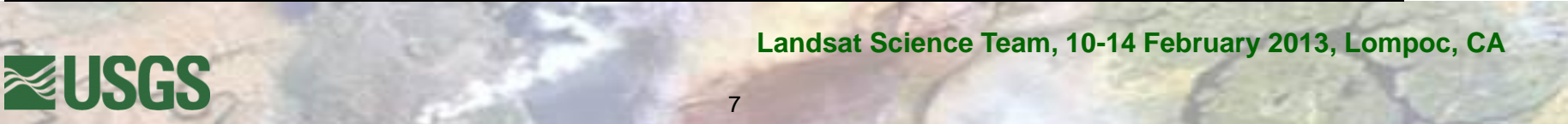
Long-Term Acquisition Plan controls

- **Vegetation phenology quantified by seasonality files or NDVI**
- **Cloud predictions avoid acquisitions of “relatively” cloudy data**
- **Cloud climatology quantify “relatively” cloudy data**
- **Automatic Cloud Cover Assessments of acquired images identify successful acquisitions**
- **Missed opportunity boost**
- **Thematic Campaigns – requirements not well represented by seasonality: reefs, agriculture, volcanoes, glaciers,...**

Landsat Schedulers

- **The Landsat 7 scheduler and LDCM CAPE implement the Long Term Acquisition Plan (LTAP) algorithms**
 - ◆ Seasonal and thematically driven acquisitions to build a global archive
 - ◆ Special requests (emergency response, field campaigns, etc.)
 - ◆ IC Priority Masks
- **Balancing many factors, a schedule of scenes is produced**
- **Landsat 7 and LDCM will fly in 8-day offset WRS-2 orbits**

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Long-Term Acquisition Plan Status

- **Landsat 5**

- During final two years acquired under our most sophisticated LTAP.

- **Landsat 7**

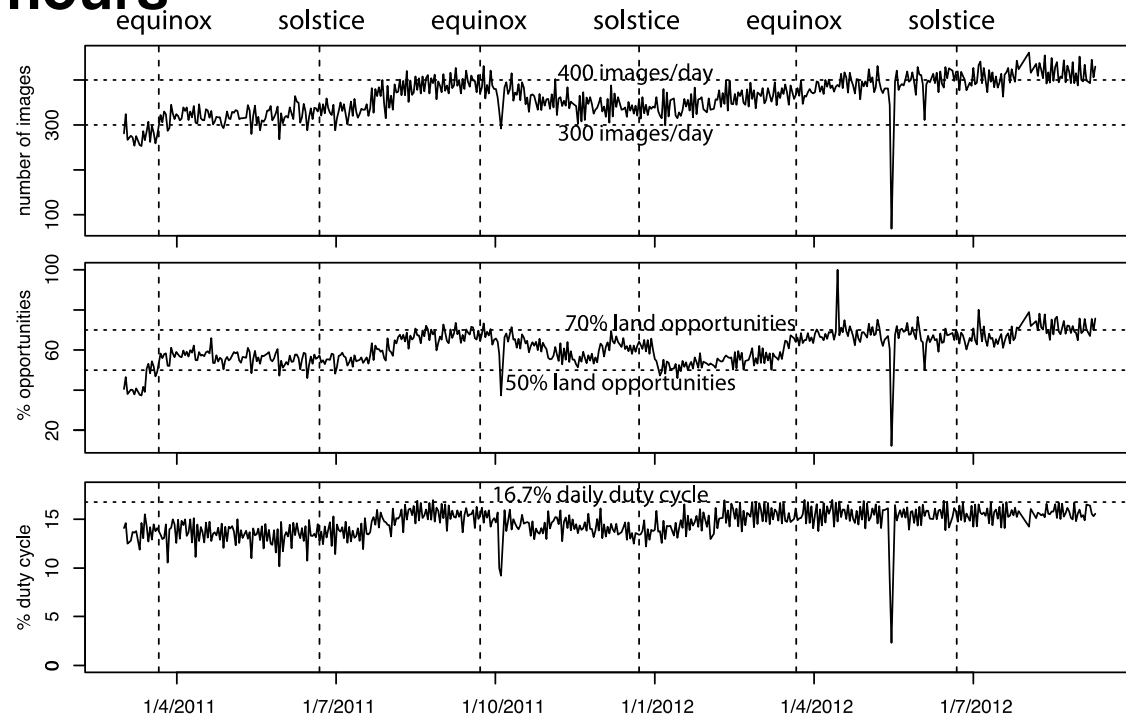
- Acquires using a formal LTAP since launch in 1999
 - Originally designed for a 250 image/day a “pay-for-view” scenario where cloud free images were highly desirable
 - Solid state recorder facilitates global acquisition of images
 - Images 350 – 450 images per day out of 540 - 630 opportunities limited by
 - duty cycle and storage capacity constraints and
 - the amount of sun lit land available on a given day
 - Since the Scan Line Corrector failure, the LTAP pursues image pairs
 - Soon to inherent functionality implemented for Landsat 5

- **Landsat 8**

- Will acquire using a formal LTAP
 - Solid state recorder will facilitate global acquisition of images
 - Will acquire about 400 images per day
 - Capable of off-nadir viewing – up to one path
 - Scheduler will evolve after transition to operations

ETM+ constraints

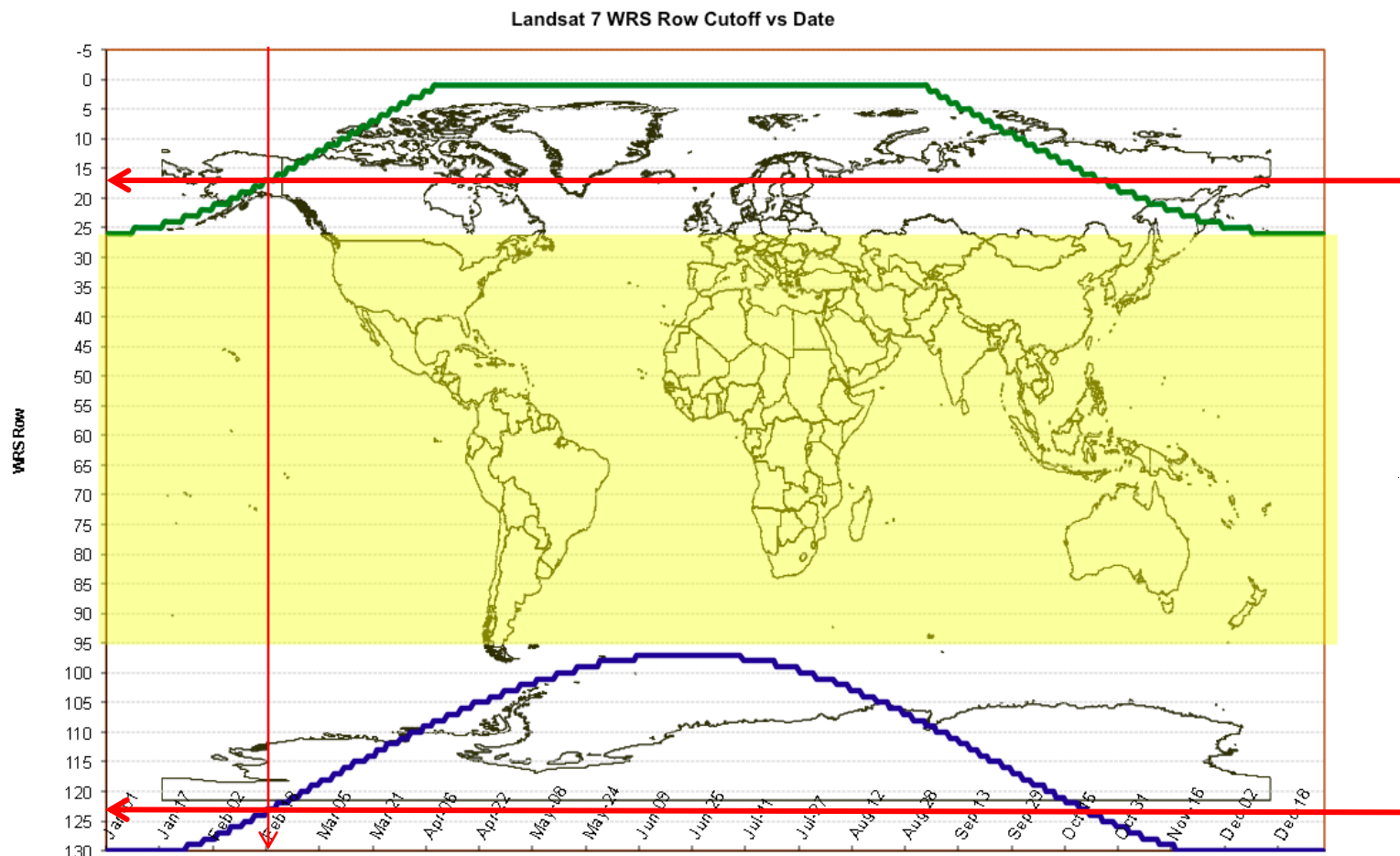
- Removed number of images constraint
- Relaxed cloud threshold constraints
- Duty cycle constraints
 - Long – 16.7% in 23 hours
 - Medium/long – 131 of 600 min (6 orbits)
 - Medium – 52 of 200 min (2 orbits)
 - Short – 34 of 100 min (1 orbit)



Cloud Avoidance & Sun Angle

- Another component of the LTAP “when” is related to avoiding clouds, sometimes
- Two types of data play into this:
 - ◆ NCEP global weather forecast (cloud cover dataset)
 - Obtained from NCEP four times a day
 - Regridded into path-row values
 - ◆ Global cloud cover climatology reference dataset
 - “Static” dataset provided external to CAPE
 - Average cloud fraction for each path, row, for periods of time
 - Shifting to MODIS Cloud Fraction which is synchronized to Landsat
- LTAP is constrained by Sun elevation (15° N, 5° S)
 - ◆ Constraint can be overridden for special requests
 - ◆ Night acquisitions are only by special request

L7 & 8 Sun Angle Constrained Coverage



Imaging presently allowed (sun angle constraint) between the red horizontal lines

Seasonality

- With the current approach, the seasonality database table defines when and where to acquire data
 - ◆ L5 & L7 are moving to an NDVI-measurement approach
 - ◆ LDCM may be modified to follow a similar approach after LDCM is operational
- The seasonality table consists of records like these:

Path	Row	Start	End	Mode	Priority
35	31	01-Jan-12	31-Dec-12	0	9999
35	32	01-Jan-12	31-Dec-12	0	9999
35	33	01-Jan-12	31-Dec-12	0	9999
86	54	01-Jan-12	31-Dec-12	1	50

Land Database

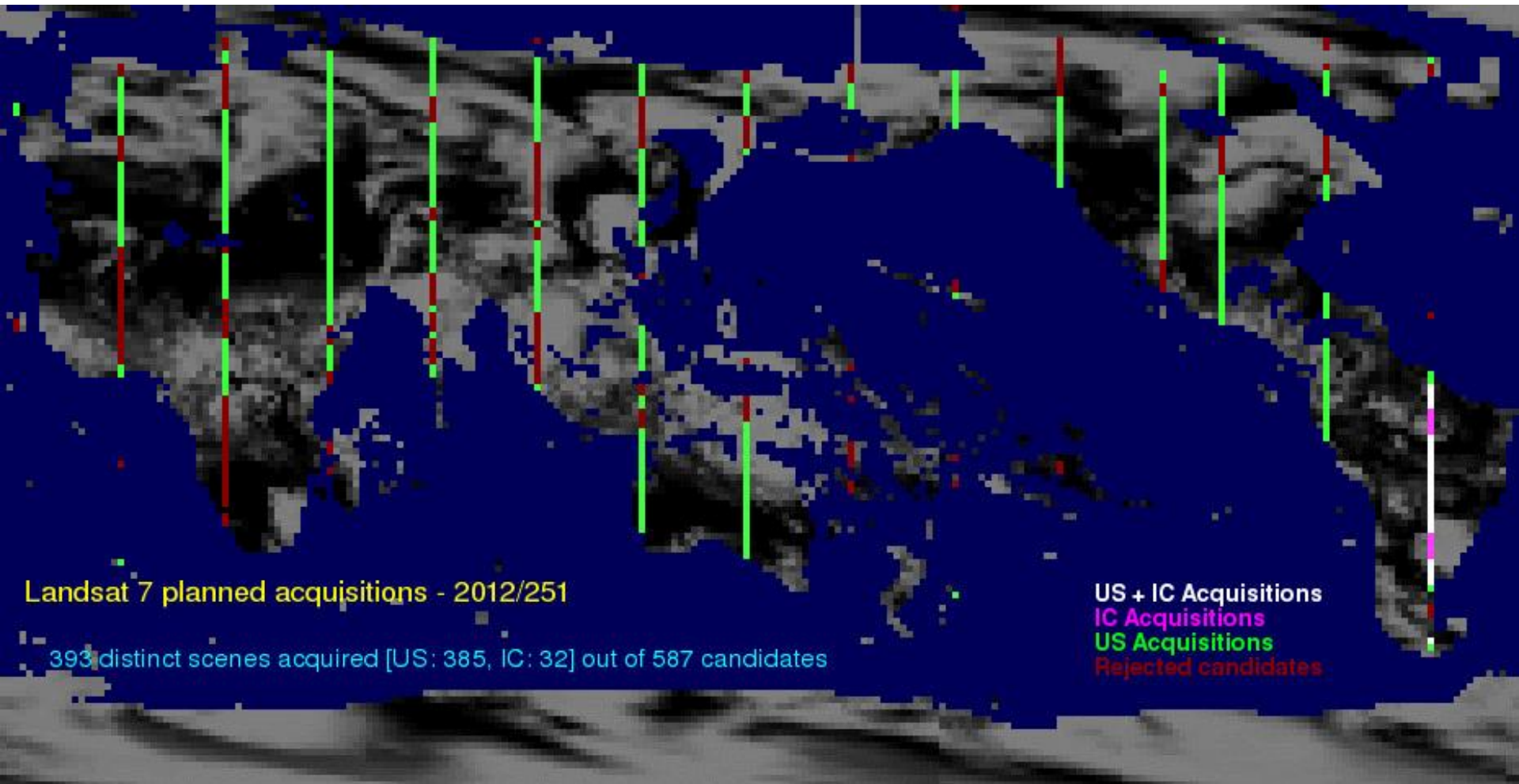
- **The Land Database associates handy landcover types and political definitions with path/row information**
 - ◆ Can be multiple entries for one path/row, and multiple entries for one tag
- **This is useful for querying manually to find out path/row information when building or managing requests**
- **Example records:**

<u>Path</u>	<u>row</u>	<u>description</u>
86 53		Marshall Islands
35 33		CONUS-Colorado
35 33		CONUS-Utah
35 33		USA-Colorado
35 33		USA-Utah
122	65	Indonesia-Java
122	65	tropical rainforest niche

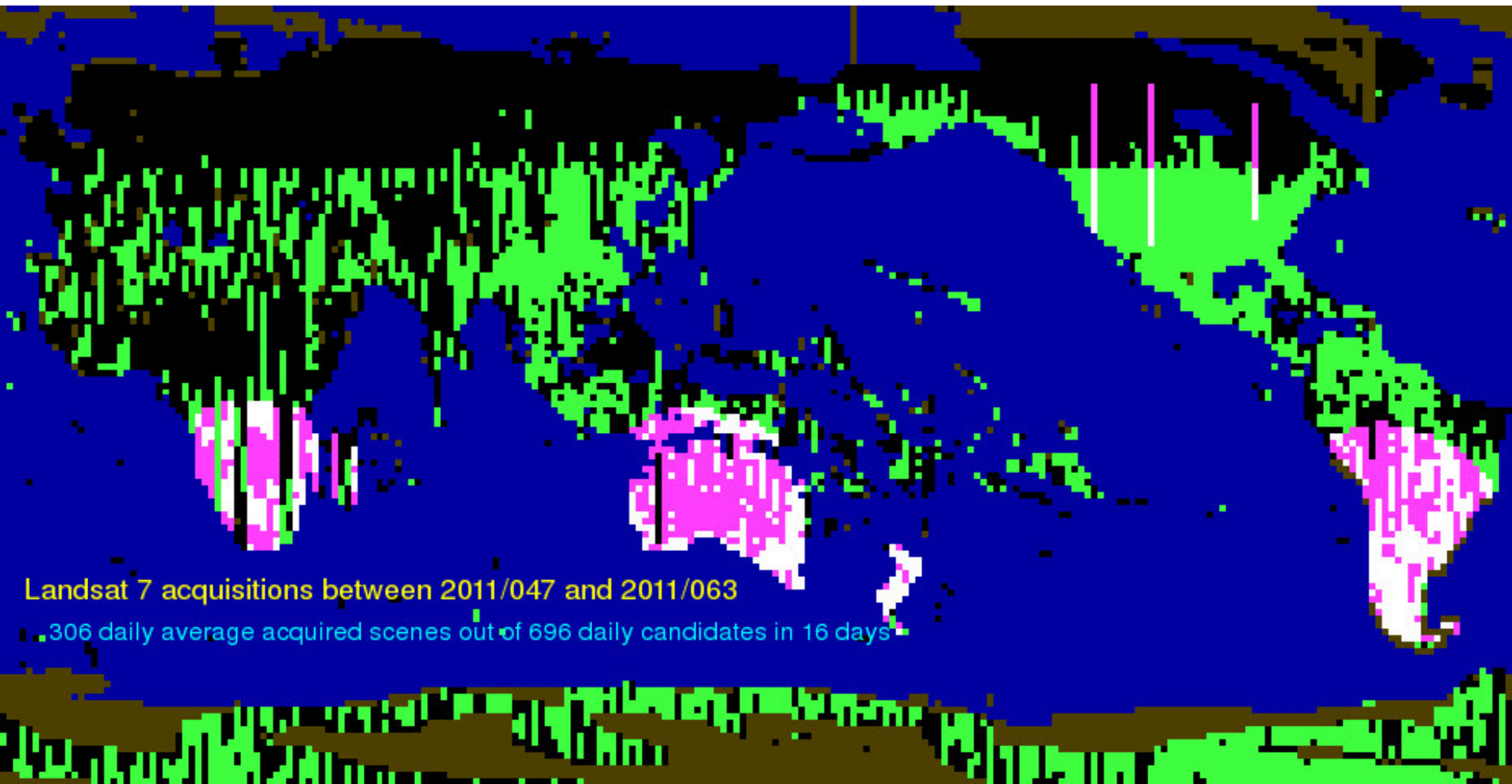
Priority-Based Scheduling

- **Part of the LTAP approach is to use a priority-based scheduling approach**
 - ◆ All candidate 'requests' are given a priority value
- **A host of scheduling rules modify priority values**
 - ◆ Example rules:
 - Boost priority for relatively low cloud prediction
 - Discount cloud cover if cloud prediction confidence is low
 - Boost priority based on remaining opportunities to collect
 - Boost priority when multiple sources request same scene
 - Boost priority if predicted cloud cover is low (relative to climatology)
 - Boost priority for high NDVI
- **The scheduling engine employs the final priority scores in order to determine the final schedule**

Daily acquisitions with cloud prediction



Landsat 16-day acquisition maps



Landsat 7 Seasonality Plots for Path 199

Graphs show relationship between NDVI, seasonality records, and acquisitions from Norway to Liberia.

Circles (black: ETM, red: ETM slc-off, blue: TM) are images acquired with circles proportional to cloud cover (small – high, large – low)

Yellow vertical lines are sun elevation cut off dates
Magenta line is MODIS Monthly Cloud Fraction

Red (acquire always) and blue (acquire once) lines represent the discrete seasonality records

NDVI

Max upper dotted line

Mean + SD

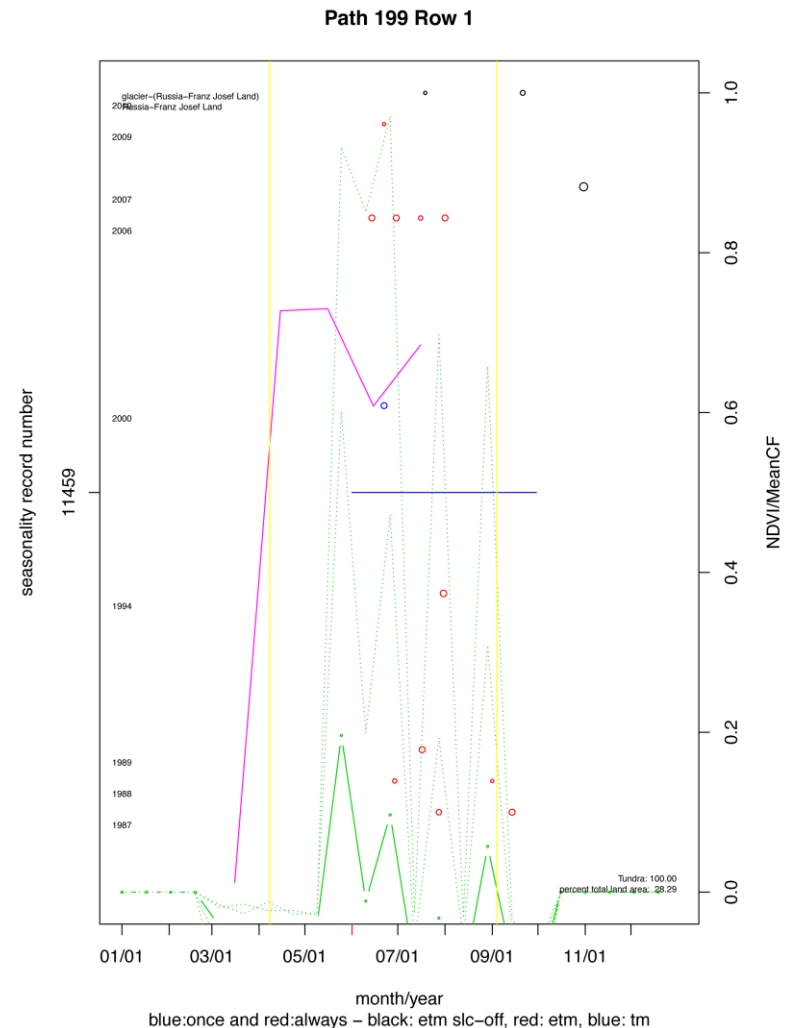
Mean green circles

Mean – SD

Min lower dotted line

Upper left text – land database records

Lower left text – ecosystems



LTAP in Summary

- **Path 199 example – lessons observed**

- Acquire too frequently over arid areas
- Acquire too seldom over persistently-cloudy vegetated areas
- The need to balance the cost of acquiring a high proportion of cloudy data with the need for finding the rare cloud-free sub-images is compounded by the low confidence in the cloud predictions in the tropics.
- The use of priorities derived from NDVI (which is attenuated by clouds...) and the incorporation of cloud confidence should help us find a better balance.

- **LTAP similarities**

- Acquire 60-70% of opportunities
- Always over the conterminous US
- Somewhat less over deserts and snow
- In general about 10-15 images per year for a typical vegetated path/row
- High latitudes are sun limited, but acquire at same rate as other vegetated sites during their growing season.
- Boreal, tropical and Antarctica campaigns help compensate for lack of opportunity caused by clouds or very short season.

LTAP differences

- **Landsat 7**
 - Discrete seasonality record phenology derived from AVHRR NDVI
 - ISCCP cloud climatology
 - Increased acquisitions from 300 to 380 images/day in 2011
 - Hierarchical thematic campaign manager
 - 1-degree NCEP cloud prediction
- **Landsat 7 Spring 2013 (first implemented for Landsat 5)**
 - Probabilities derived directly from NDVI-based phenology
 - MODIS cloud climatology
 - Cloud prediction confidence
 - 0.5-degree NCEP cloud prediction
- **Landsat 8**
 - LTAP is frozen at Landsat 7 LTAP circa September 2008
 - Modeling to evaluate and tune Landsat 8 LTAP is planned for 2012
 - Expected improved geometry of OLI/TIRS increases value of cloudy data

Agenda

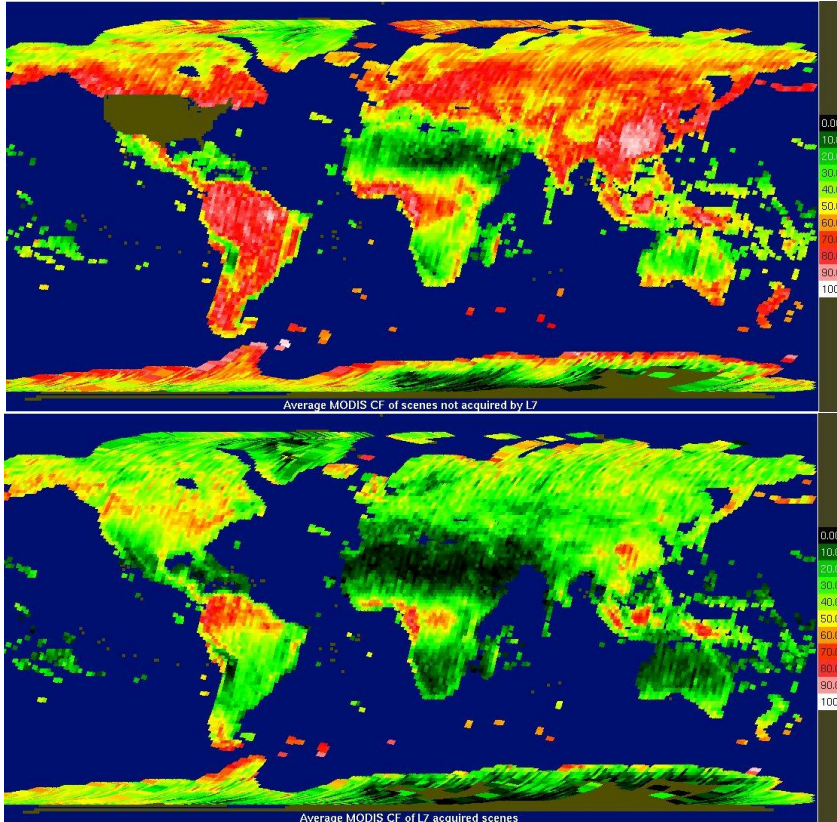
- The Landsat Long-Term Acquisition Plan
- **LTAP modeling**
- Special Requests for Acquisition

LTAP models

- **Evaluate new input data sets**
 - ◆ Cloud predictions
 - ◆ Cloud climatology
 - ◆ Phenology
- **Tune parameters**
- **Solid State Recorder management**
- **Campaign evaluation**

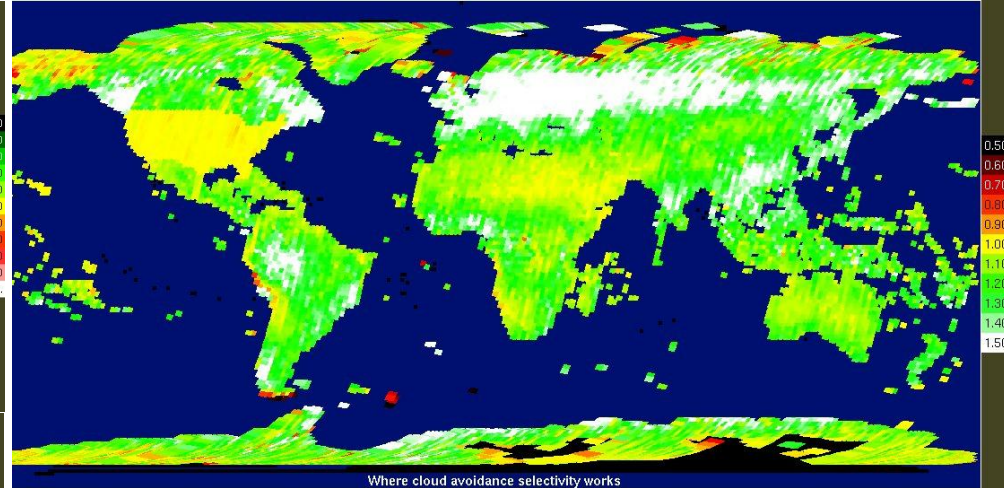
MODIS Cloud Fraction as modeling tool

Average MODIS Cloud Fraction
not acquired by Landsat



Average MODIS Cloud Fraction
acquired by Landsat

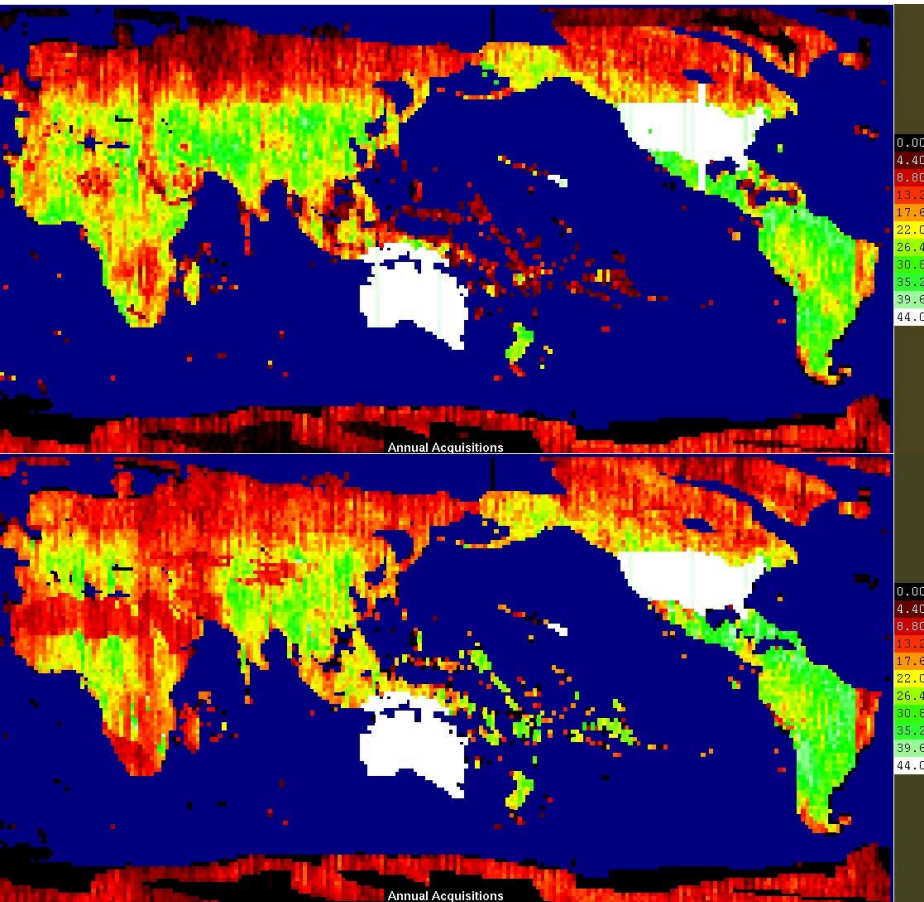
% clear scenes collected/
% clear scenes all opportunities



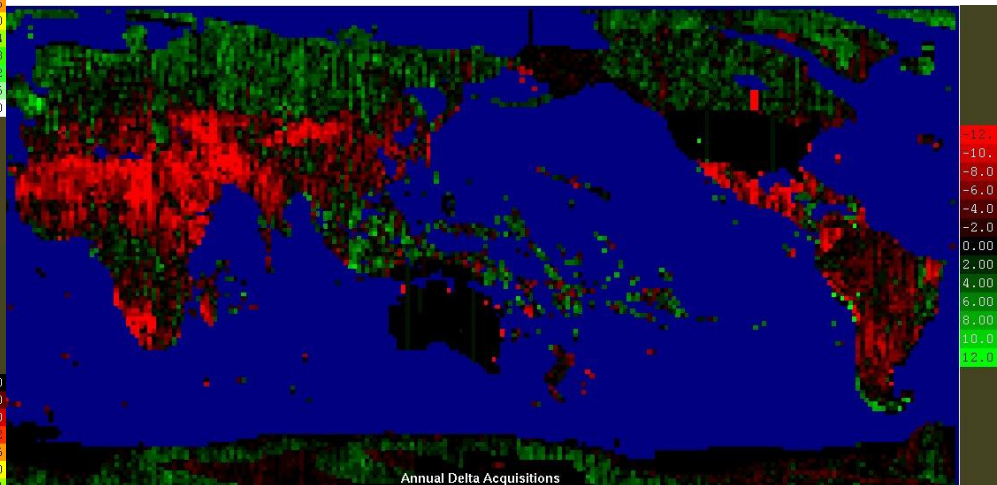
- Yellow: cloud avoidance yields no advantage
- Green to white: some advantage
- White: clear scenes acquired 50% greater than proportion in population
- black and red: cloud avoidance rarely detrimental

New Landsat 7 LTAP 2-year model run

- Goal: Redistribute consistently clear scenes to persistently cloudy areas



Operations Model



Green = more coverage in new LTAP-7. Red = less coverage.

New LTAP-7 example run

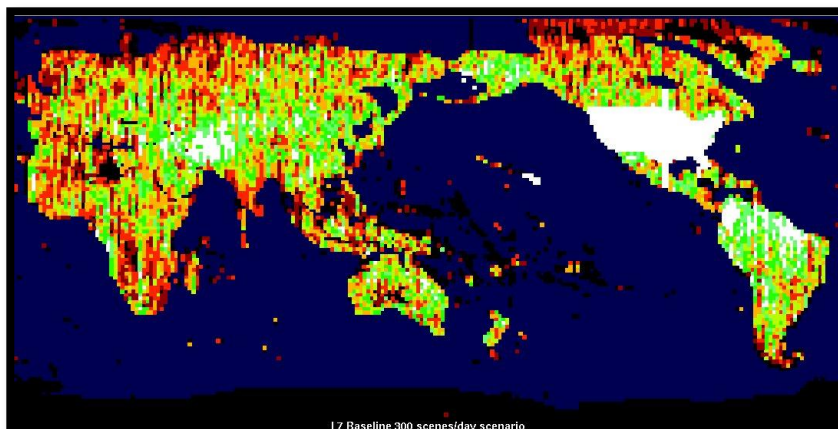
Landsat 7 Model: Increase acquisition

- 300 versus 350 scenes per day

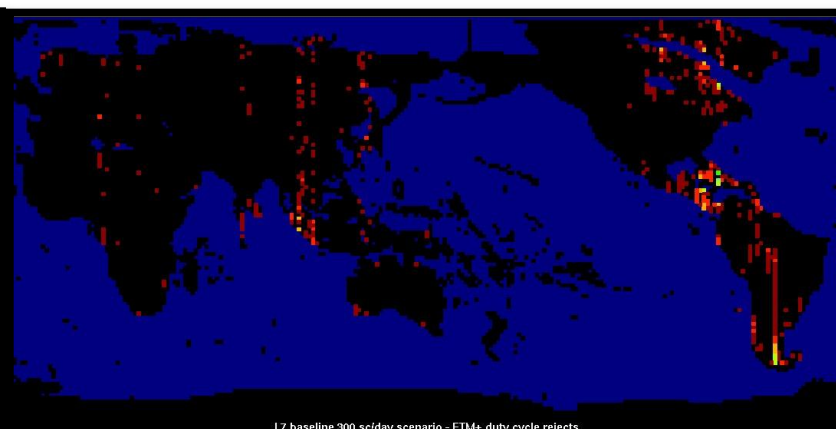
Scenes acquired

300 scenes per day

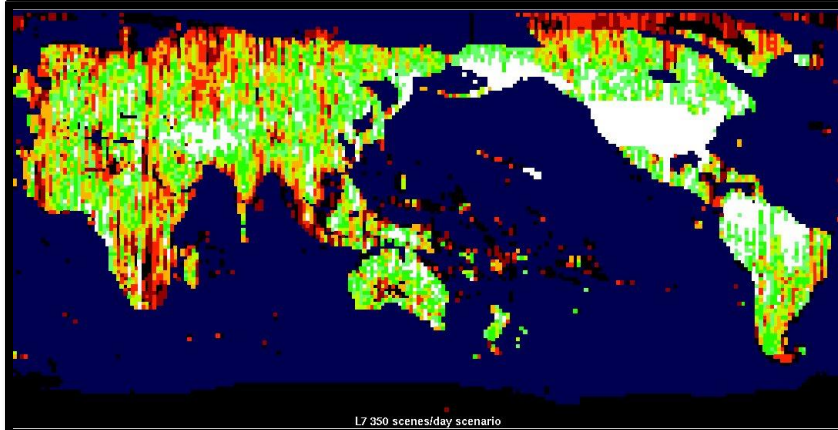
Scenes rejected by duty cycle constraint



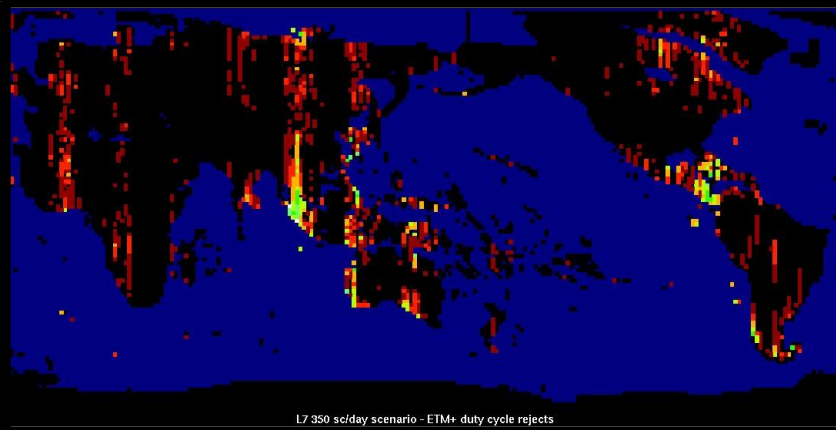
L7 Baseline 300 scenes/day scenario



L7 baseline 300 sc/day scenario - ETM+ duty cycle rejects



L7 350 scenes/day scenario



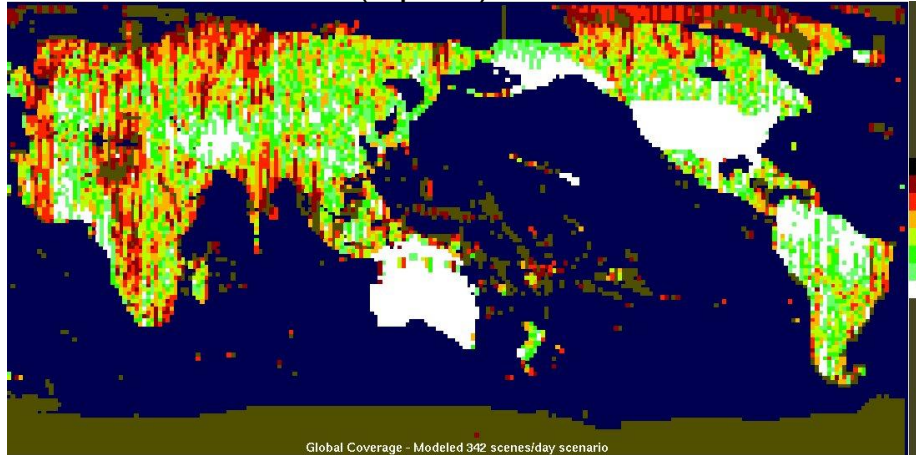
L7 350 sc/day scenario - ETM+ duty cycle rejects

350 scenes per day

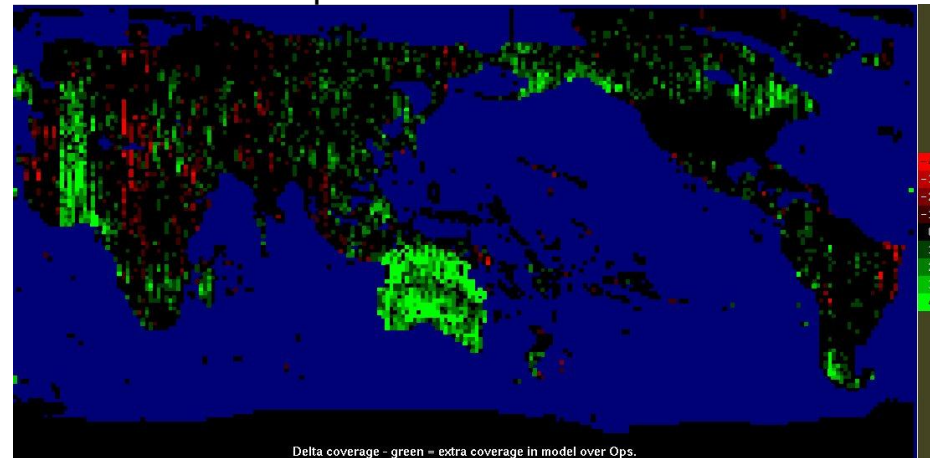
LTAP models: download opportunities

- ASN altered configuration

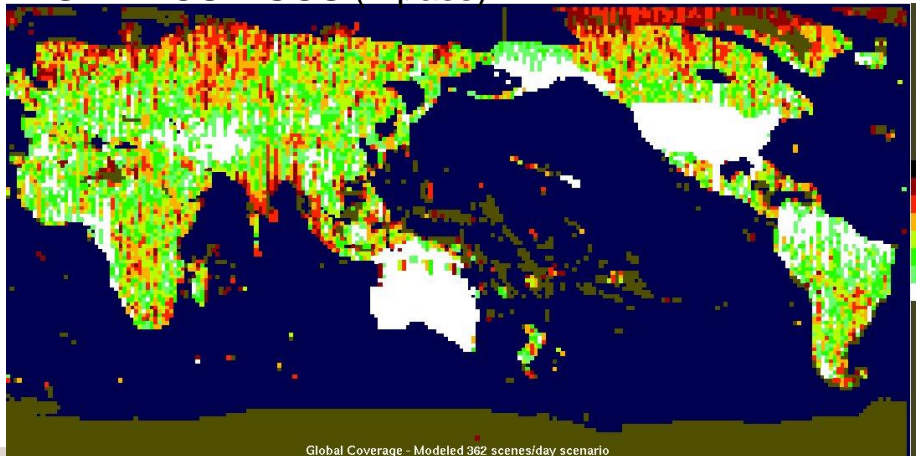
ASN + LGS + SGS (1 pass)



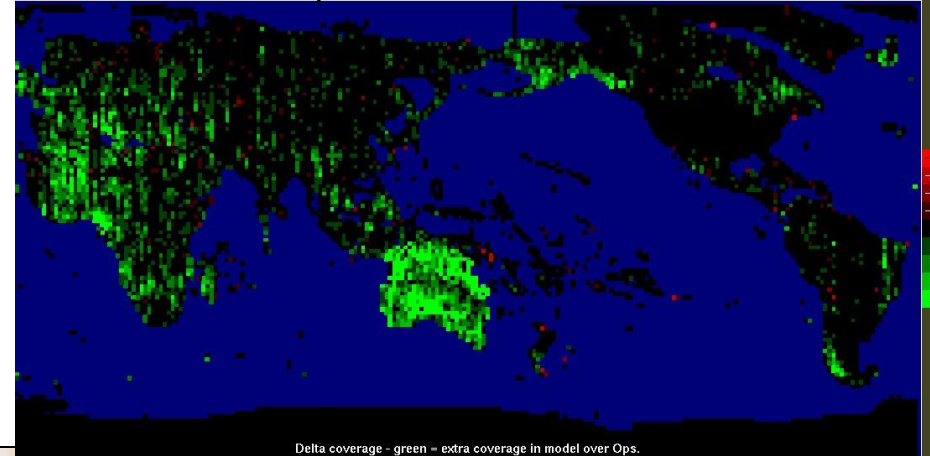
Difference with ops



ASN + LGS + SGS (2 pass)



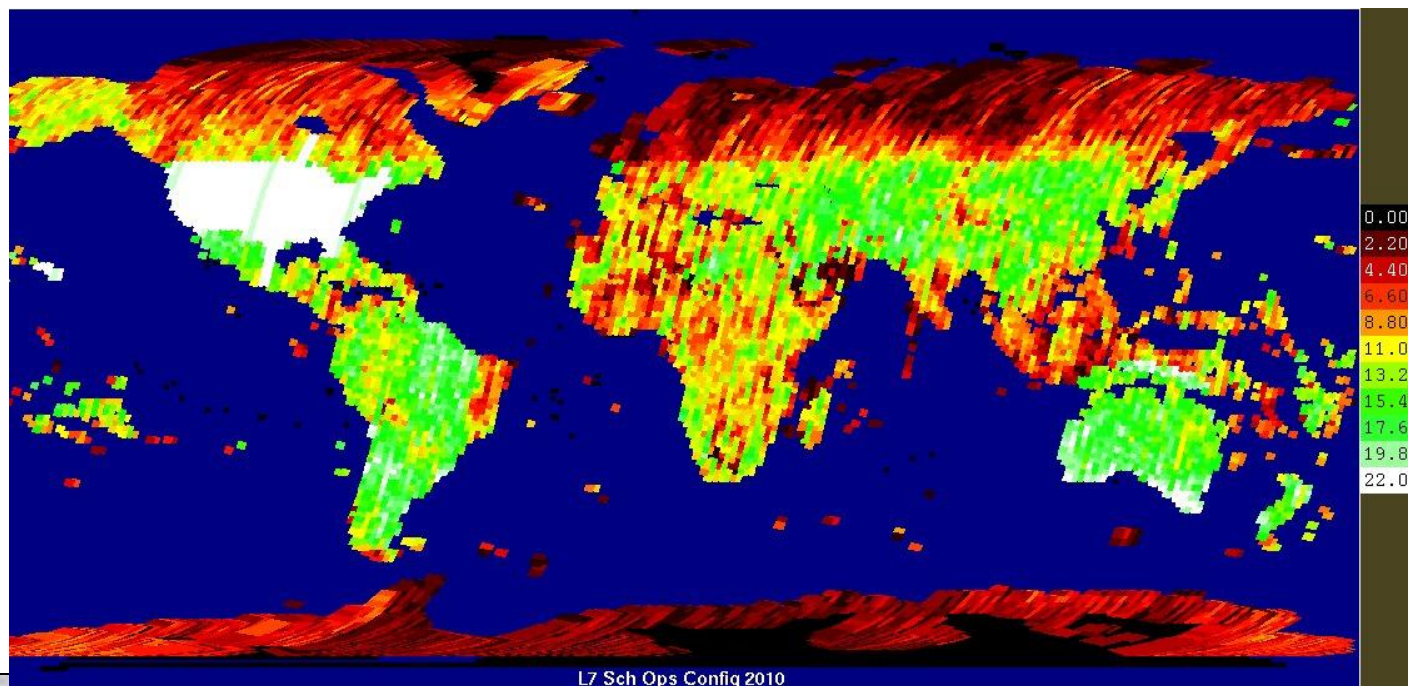
Difference with ops



Example LTAP models

● Evidence of SSR limitations over eastern Brazil

- ◆ Brazil scenes no longer stored on the SSR
- ◆ Scenes are downloaded to CUB
- ◆ Increased acquisitions over Amazon
- ◆ SSR space available for use elsewhere



L7 Sch Ops Config 2010

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Agenda

- The Landsat Long-Term Acquisition Plan
- LTAP modeling
- **Special Requests for Acquisition**

Special Requests: the exception, not the rule

- Individual User Requests
 - ◆ limited scope in time or space
 - ◆ will not impact the GAR
 - ◆ priorities range from low to high
 - ◆ field campaigns get higher priority
- Science Campaign Requests
 - ◆ large areas
 - ◆ modeled prior to approval
 - ◆ priorities range from low to high
 - ◆ field campaigns get higher priority
- Ground Look Calibration Requests
 - ◆ for specific test sites
 - ◆ often long term with field campaigns
 - ◆ high priority
- Emergency Nadir Requests
 - ◆ small areas and short term
 - ◆ disregard cloud cover and sun angle
 - ◆ highest priority
- Emergency Off-Nadir Requests
 - ◆ very small areas and short term
 - ◆ only Off-Nadir requests trump “CONUS”
 - ◆ causes lost opportunities in nadir
 - ◆ disregard cloud cover and sun angle
 - ◆ highest priority
- No request is approved for longer than one year
- All Special Requests are adjudicated by the Data Acquisition Manager (DAM)

The vast majority of acquisitions by volume are “algorithmically” scheduled – the Landsat LTAP is designed to create an environmental record of the Earth

Ground Look Calibration (GLC) Requests

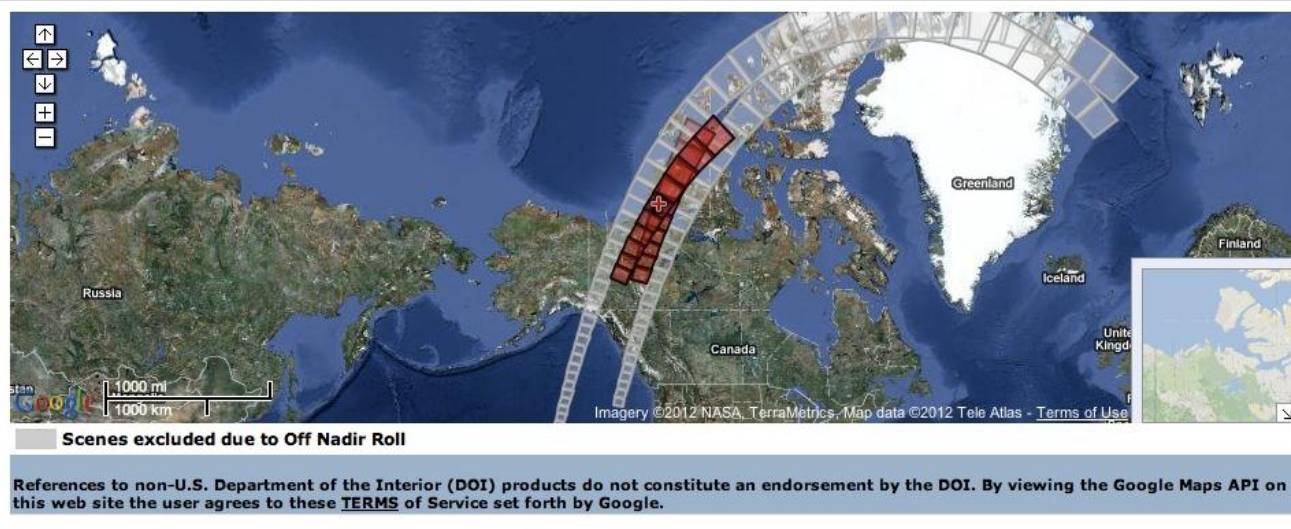
- **Most GLC requests are renewed every year**
- **Examples include:**
 - ◆ Geometric supersites (one for each of 16 WRS cycle days)
 - ◆ Pseudo Invariant Calibration (PIC) sites
 - ◆ Vicarious calibration sites
 - ◆ Routine spatial targets (like Lake Ponchartrain bridge)
- **Lots of Cal/Val scheduling requests are not WRS-2 based in nature and so are scheduled via Flexplan, not CAPE**

Off-Nadir Special Request

- Policy guidelines have been developed
- Off-nadir requests have consequences
 - ◆ 25 scenes of data are lost during every “slew”
 - ◆ No cloud avoidance
 - ◆ Images acquired are “engineering” quality
 - ◆ Special requests are not accepted for CONUS – We always acquire

Review and Edit

Show/Hide	Path/Row	Look Angle	Date	Select
Show	53/6-15	Left 19.9	10/29/2012	<input type="radio"/>
Hide	60/5-14	Right 9.0	10/30/2012	<input checked="" type="radio"/>
Hide	58/6-15	Nadir	11/1/2012	<input type="radio"/>
Hide	56/6-15	Left 7.7	11/3/2012	<input type="radio"/>
Hide	54/6-15	Left 16.0	11/5/2012	<input type="radio"/>
Hide	61/5-14	Right 12.9	11/6/2012	<input type="radio"/>
Hide	59/6-15	Nadir	11/8/2012	<input type="radio"/>
Hide	57/6-15	Nadir	11/10/2012	<input type="radio"/>
Hide	55/6-15	Left 11.9	11/12/2012	<input type="radio"/>
Show	62/4-14	Right 16.7	11/13/2012	<input type="radio"/>



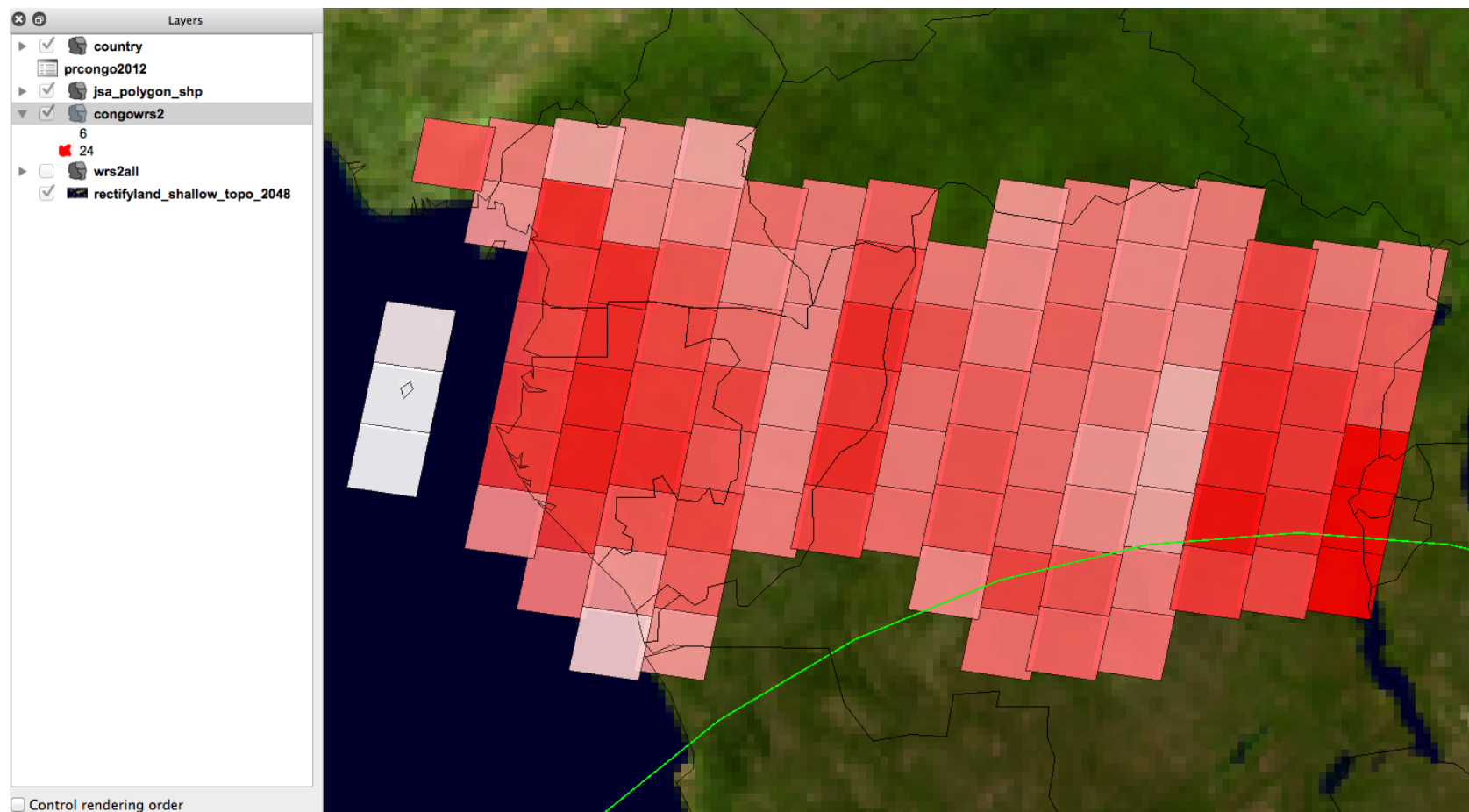
- ◆ Left and right Off-Nadir looks from paths 53 and 62 respectively and the nadir scenes lost for each as a result

Campaigns

- **Seasonality-driven acquisitions are only one component of the global acquisition strategy**
- **Science campaigns serve two functions:**
 - ◆ To serve short term goals, for example
 - Global Land Survey
 - under water hazards identification
 - ◆ To supplement the LTAP by addressing acquisition requirements not well characterized by phenology.
 - Irrigated agriculture
 - Antarctica
 - Reefs
 - Glaciers
 - Volcanoes
 - Persistently cloudy regions: Boreal or tropical forests

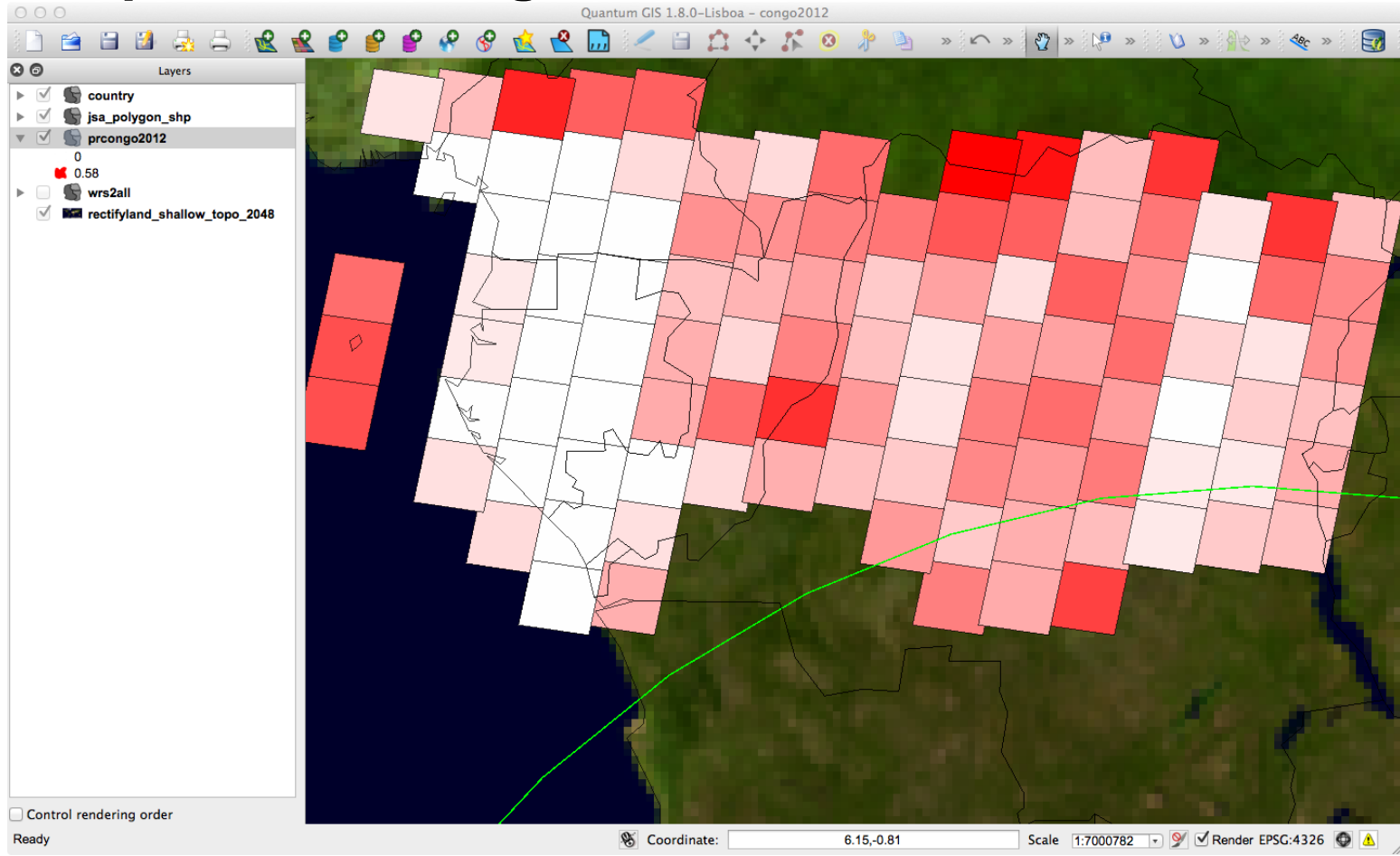
Congo 2012 Campaign

- Total images



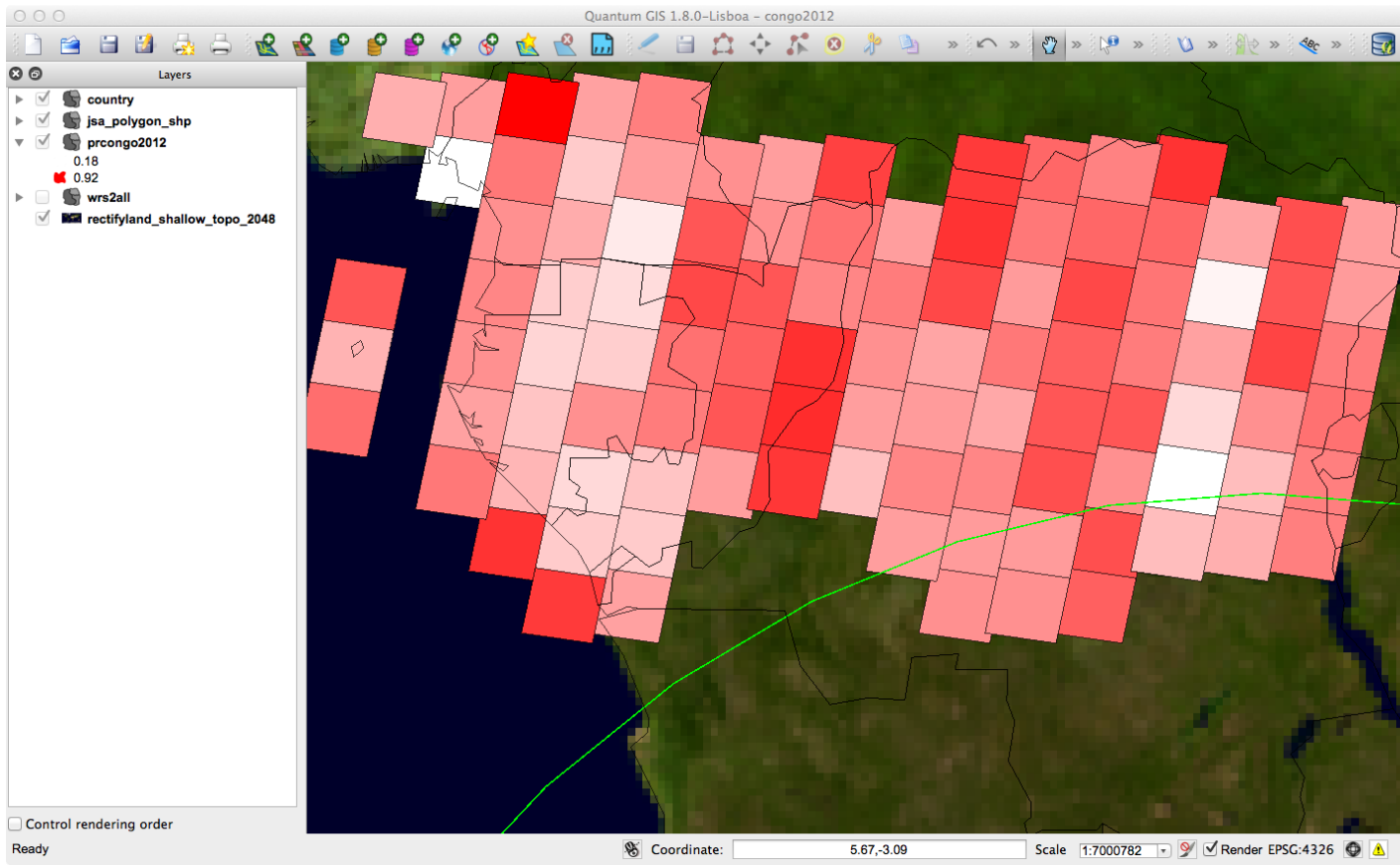
Congo 2012 Campaign

- Proportion of images with less than 20% cloud cover



Congo 2012 Campaign

- Proportion of images with cloud cover less than monthly climatological cloud fraction

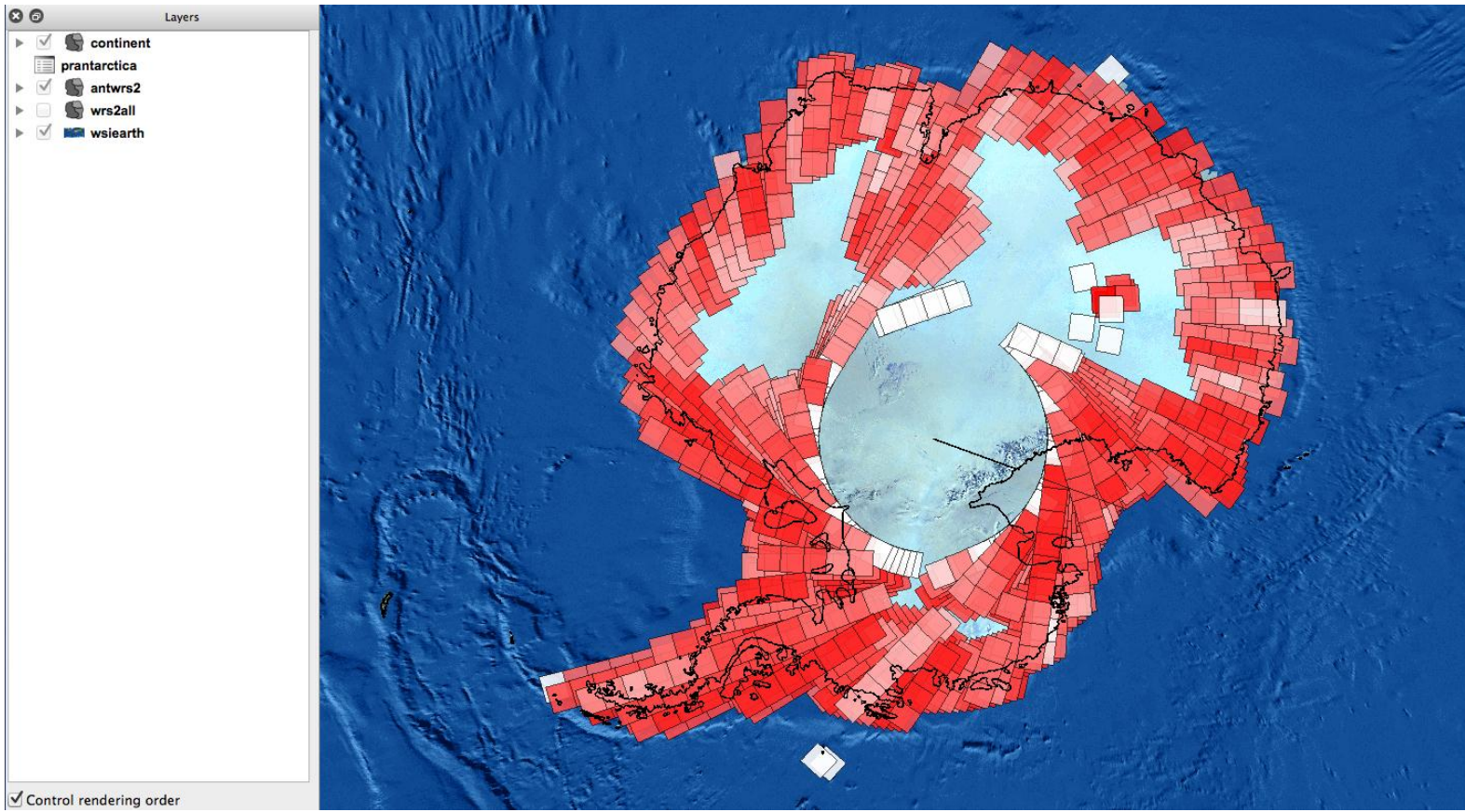


Coordination of Landsat 7 & 8 Schedules

- Landsat 7 has duty cycle penalties for short intervals
- Landsat 7 is less effective than Landsat 8 over water and over snow and ice
- Landsat 8 does not have duty cycle penalties for short intervals
- Landsat 8's improved dynamic range and cloud detection performs better over snow, ice and water
- Reduce the use of Landsat 7 for island, ocean and Antarctica scenes
- Increase the use of Landsat 7 for continental land masses

Antarctica Campaign (Fall 2012-present)

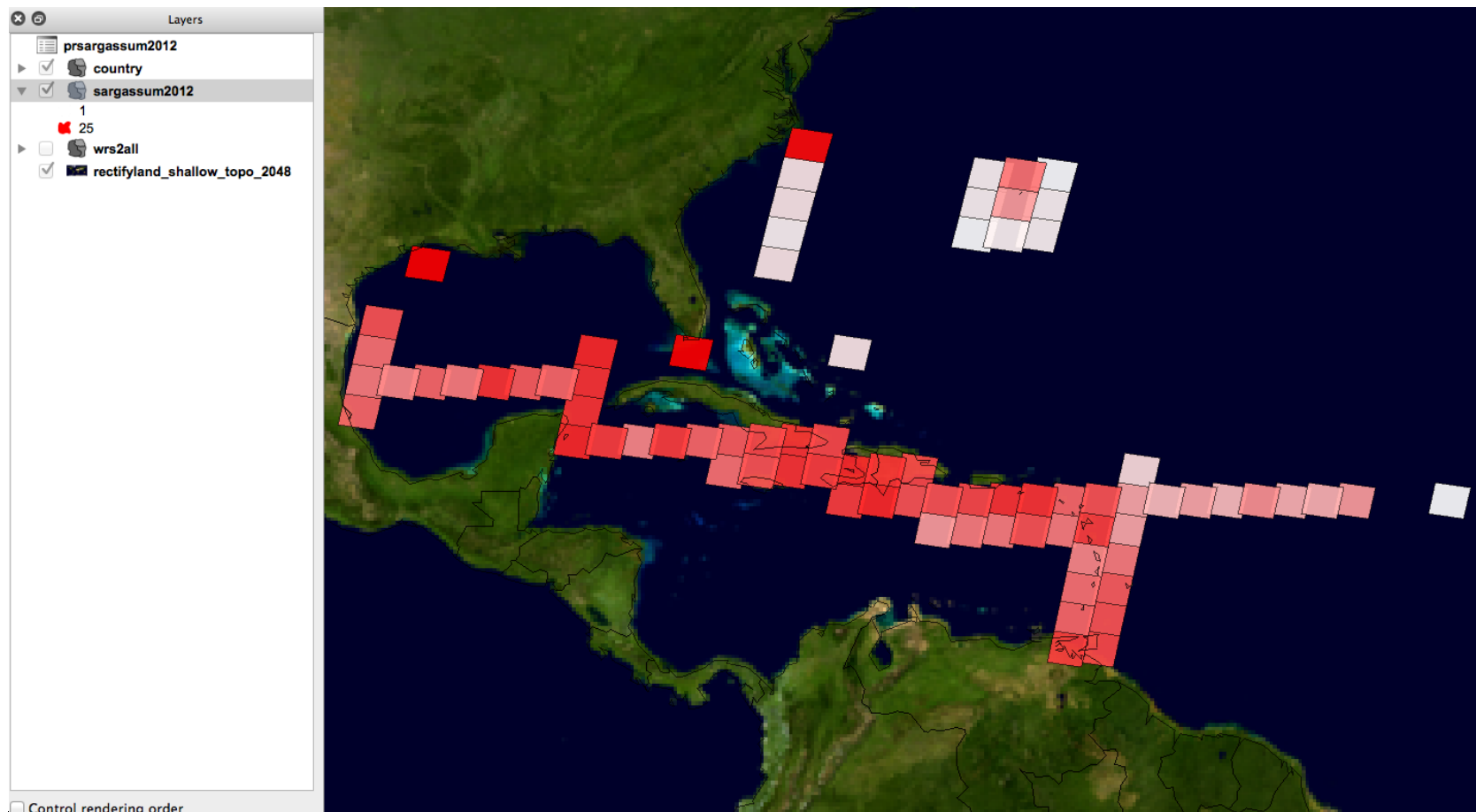
- Total images, 0: white, 7 red



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Sargassum 2012 Campaign

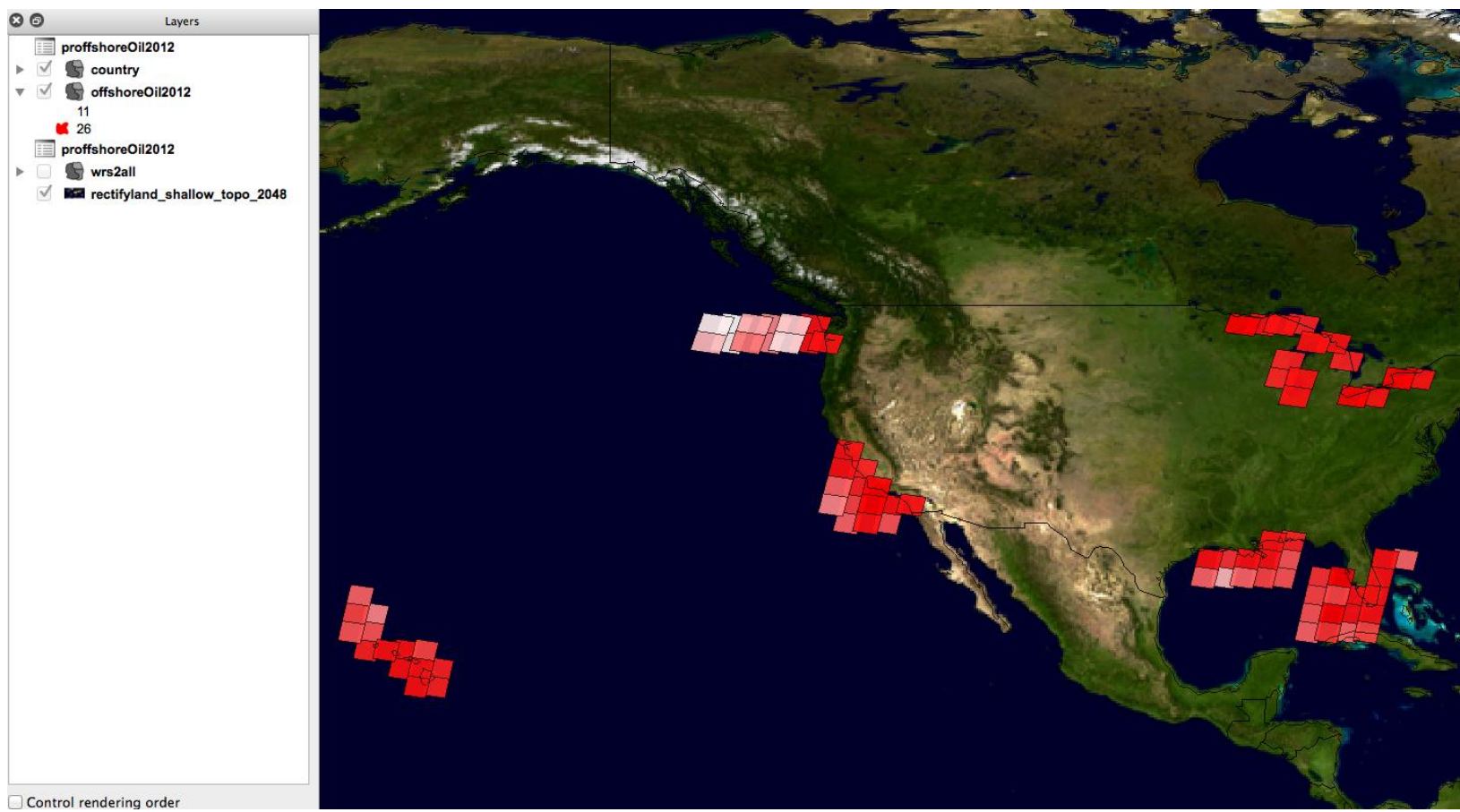
- Total images



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Offshore oil monitoring 2012 Campaign

- Total images



Landsat 7 & 8 operational schedule reports and maps

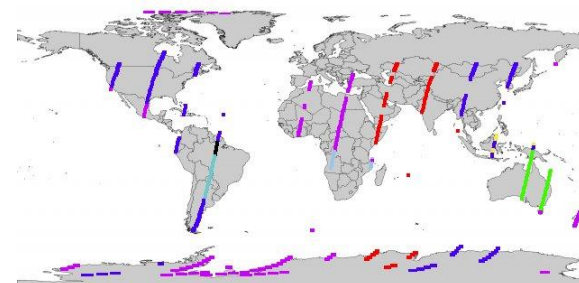
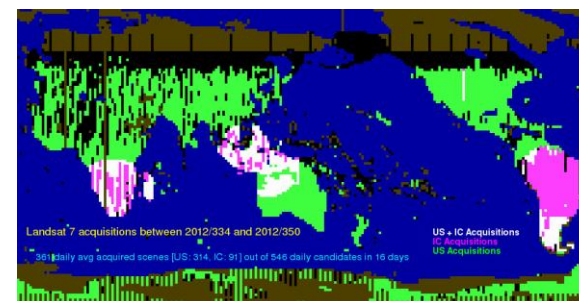
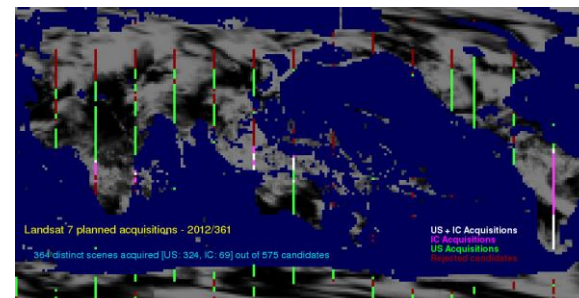
- Operational scheduling reports
 - ◆ Parent summary reports
 - ◆ Child summary reports
 - ◆ Child detail reports
- Operational scheduling maps
 - ◆ Next day schedules overlain on predicted cloud cover
 - ◆ Previous 16-day cycle
 - ◆ Next day and archived schedules in web mapping service

Operational scheduling reports

- **Summary report of success of parent Special Requests (IUR, SC, GLC, Emergency) sorted by Request #.**
 - ◆ The fields shall be in this order: Special Request #, short title, request type, start date, end date, priority, cloud cover threshold, # of scenes in request, # of opportunities in request, # of opportunities to date, completeness percent (# opp to date/# opp in request), # of images acquired to date, # of clear images acquired, # of images rejected.
 - ◆ The report shall be as a table in a doc file format. Report name will be: L8SpecialRequest_ParentSummary_yyyymmdd.doc
- **Summary report of success of child Special Requests (IUR, SC, GLC, Emergency) grouped by parent request and sorted by path/row within parent request.**
 - ◆ The fields shall be in this order: Special Request #, short title, path, row, # of opportunities to date, # of images acquired to date, # of clear images acquired, # of images rejected.
 - ◆ The report shall be in the CSV file format. Report name will be: L8SpecialRequest_ChildSummary_yyyymmdd.csv
- **Detail report of all child Special Requests (IUR, SC, GLC, Emergency) grouped by parent request and sorted by path/row/acquire time within parent request.**
 - ◆ The fields shall be in this order: Special Request #, short title, path, row, acquire time, disposition (acquired- ACCA or reason for rejection).
 - ◆ The report shall be in the CSV file format. Report name will be: L8SpecialRequest_ChildDetail_yyyymmdd.csv

Operational scheduling maps

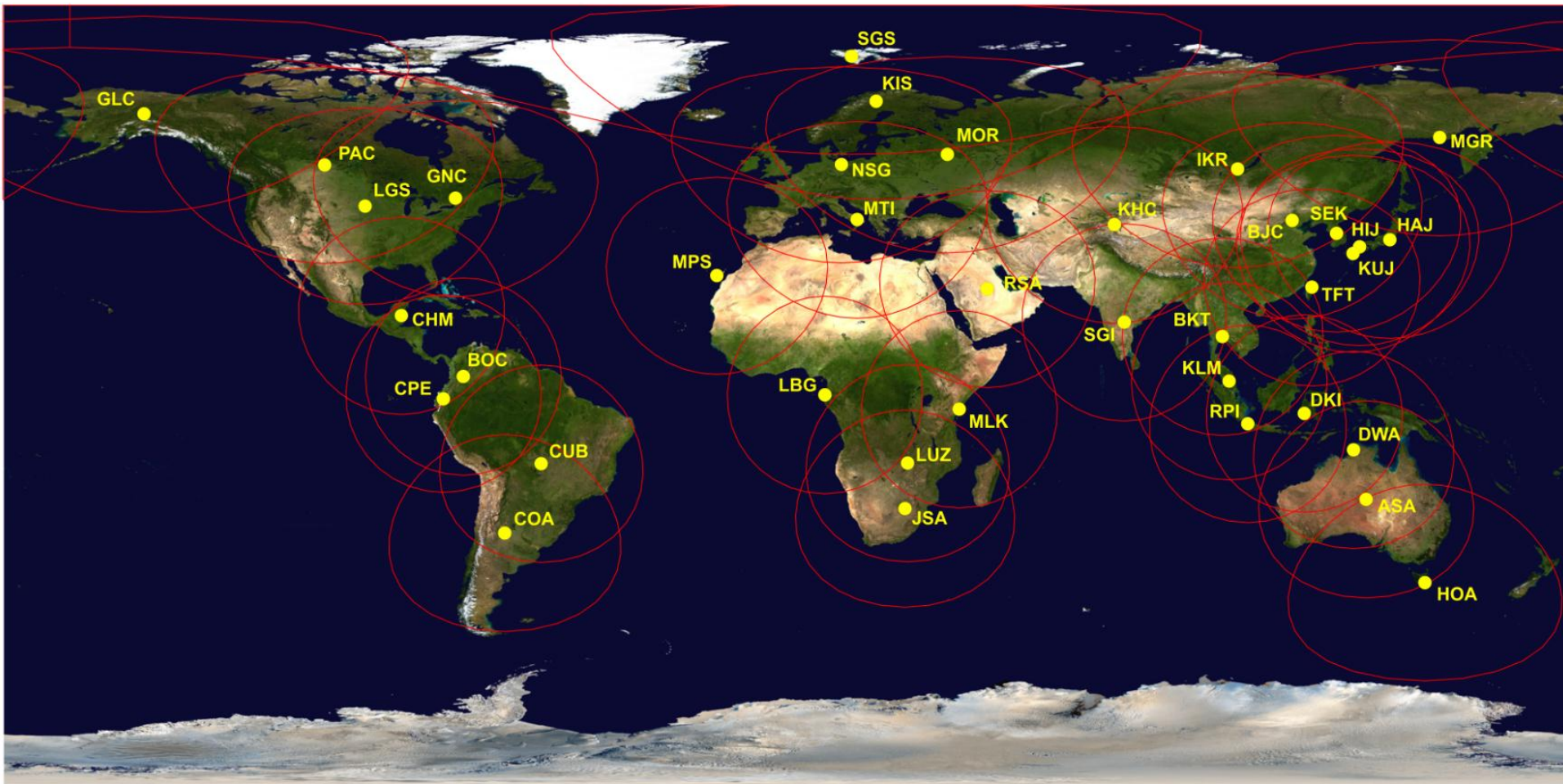
- **Next day schedules overlain on predicted cloud cover**
 - ◆ Delivered by the MOCs
- **Previous 16-day cycle**
 - ◆ Delivered by the MOCs
- **Next day and archived schedules in web mapping service**
 - ◆ Generated from the STS by the UP



International Cooperators

- **IC's interact for scheduling purposes in two ways**
 - ◆ Submission of special requests
 - ◆ Submission of a whole-mask relative priority assessment
- **IC Priority Mask Tool**
 - ◆ UP provides a tool for submitting these datasets
 - ◆ CAPE translates this input into a large parent special request with child requests for every path-row-date opportunity
- **Scheduling IC's**
 - ◆ In practice, the IC inputs serve to influence priority values for candidate scenes
 - ◆ A major modeling activity over the next year will be tuning IC priorities so high priority scenes have significant boosts that do not adversely effect the global LTAP.

Potential LDCM Reception Network



If we are able to exceed the 400 scene/day limit,
ICs may provide a means to download the additional data

Original Input File

ASA
Cyc 9-13
As of 20090106

= scheduler 5 degree circle
land scenes only

= considered land scene in database
 = considered water scene in database

1 = Priority "one" requested scene
2 = Priority "two" requested scene
3 = Priority "three" requested scene

1 = Priority "one" scene, not requested
2 = Priority "two" scene, not requested
3 = Priority "three" scene, not requested

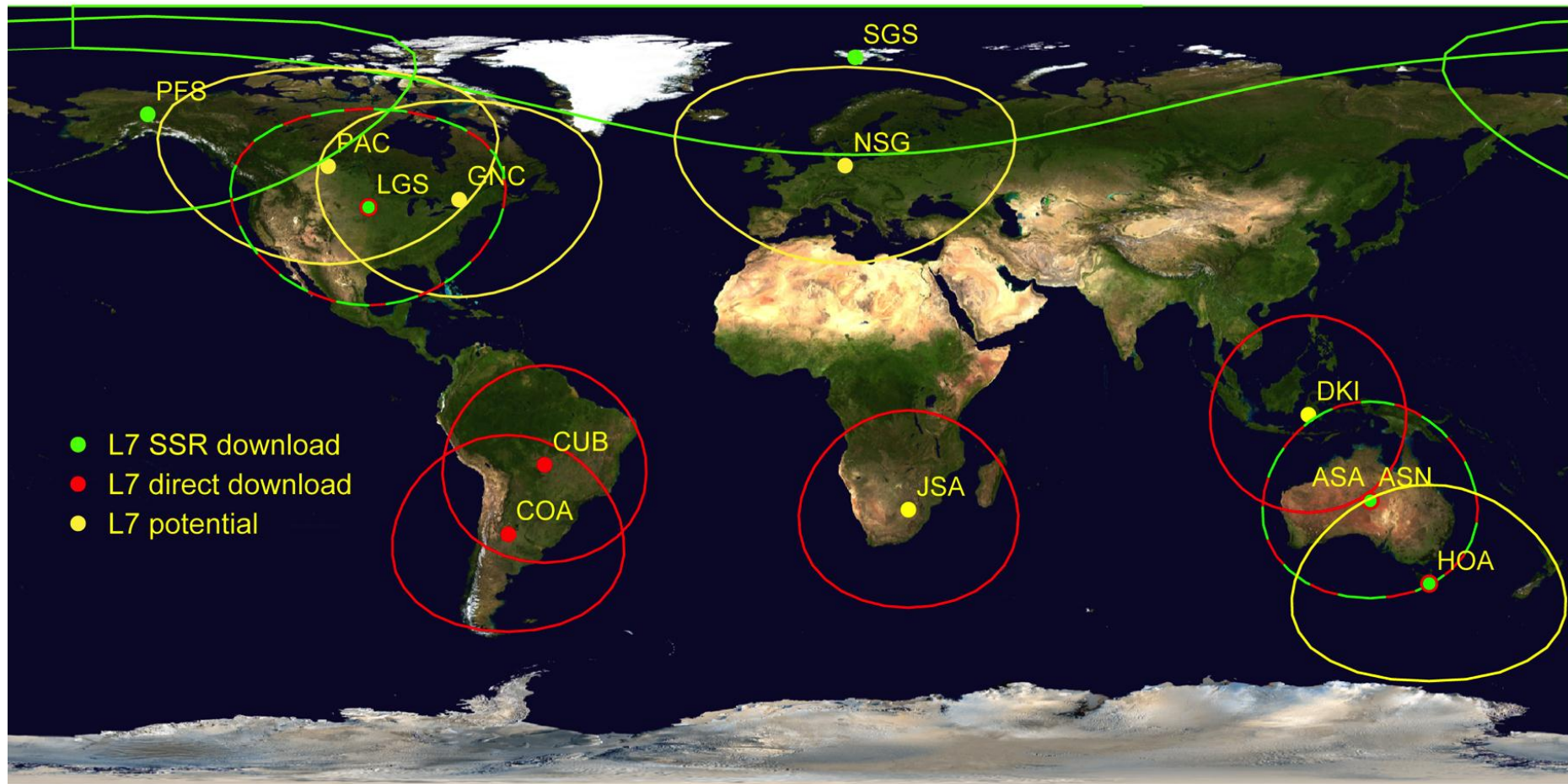
					D8	D1	D10	D3	D12	D5	D14	D7	D16	D9	D2	D11	D4	D13	D6	D15	D8	D1	D10	D3	D12	D5	D14	D7	D16	D9	D2	D11	D4	D13	D6	D15	D8	D1						
	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83					
59					3	3	3	3	3	3	3	3	3																3											13	59			
60					3	3	3	3	3	3	3	3	3	3	3	3	3	3											3											15	60			
61					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	3	3											25	61		
62					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3											24	62		
63					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3									27	63	
64					3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			26	64	
65					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			3	3	3	3	3	3	3	3	3			28	65	
66					3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3			29	66	
67									3	3	3	3	3											1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	20	67	
68											3						1	1	1	1	1				1	1	3			3	3	3	3				3				3	15	68	
69										3	3	1	1				1	1	1	1	1				2	2	1														3	15	69	
70										3	3	1	1	1	1	1	2	2	2	2	2	1			2	2	1	1	1														17	70
71												1	2	2	1	1	2	2	2	2	2	1	1		2	2	2	1	1	1	1												19	71
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74												1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	28	74		
75												1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	29	75		
76												1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	27	76		
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80												1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	30	80		
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82												1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	27	82		
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84												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19	84		
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	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83					
					D8	D1	D10	D3	D12	D5	D14	D7	D16	D9	D2	D11	D4	D13	D6	D15	D8	D1	D10	D3	D12	D5	D14	D7	D16	D9	D2	D11	D4	D13	D6	D15	D8	D1						

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Landsat 7 Reception Network

Landsat 7 Ground Stations



Empirical heuristic for new Landsat 7 ICs

- **Automated management of IC direct reception**
- **Establish criteria for overall quality**
 - ◆ If the overall success rate falls below 95% on two consecutive cycles for scenes with a priority of zero, return to recording of the LTAP scenes on the SSR using default priority.
- **Establish per scene criteria**
 - ◆ Develop a three-step priority ramp (for example, 50, 1, 0) representing the probability (LTAP default, intermediate, never on SSR respectively) of storage on the SSR.
 - ◆ If a scene is successfully acquired on four consecutive cycles, the priority is reduced one step
 - ◆ If a scene is not successfully acquired by the ground station, the priority is increased one step.
- **No guarantee of full circle – duty cycle constraints**

The future of the Landsat LTAP

- **The way forward**

- Parameter tuning will continue as new data, such as NDVI, Cloud Climatology and confidence estimates, are evaluated and implemented.
- A land ACCA score will improve the acquisition of island/coastal scenes.
- Increase focus on QA/QC of archive. Do the images acquired meet the expectations of the LTAP requirements?
- Unlimited access to data has established a new paradigm where partially cloudy data have increased value. – Increased requirement for generation of L1T products
- MODIS Cloud Fraction will permit continuous refinement of LTAP models

- **LTAP evolution will provide**

- A direct measurement of vegetative phenology augmented by permanent campaigns,
- Scene specific tuning of LTAP
- Higher resolution cloud climatology and cloud prediction, and
- An estimate of cloud prediction confidence

- **Permitting a more nuanced balance between the need for**

- Additional coverage of persistently cloudy areas, and
- Less coverage of slow changing persistently clear areas,
- While accommodating requirements distinct from scene-based phenology

The future of the Landsat LTAP

- Formal participation of Landsat Science Team in the evolution of the LTAP and feedback through informal communication are highly desired.
- The Landsat acquisition strategy remains focused on maintaining a long-term global environmental record.

Thank You!

Questions?